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NEMATOLOGY.—*The teasel nematode*, Ditylenchus dipsaci (*Kühn, 1857*), *Filipjev, 1936*.

Wilbur D. Courtney, Bureau of Plant Industry, Soils, and Agricultural Engineering. (Communicated by G. Steiner.)

Textile mills have long depended on the spiny heads or "burs" of cultivated teasel plants to produce the nap on fine woolens. Other materials have been tested for this use, but only nylon bristles have shown promise of success. Teasel culture constitutes an agricultural crop of extreme geographical limitations with the principal American planting being located in the Pacific Northwest.

The teasel is a biennial with a rosette of stout, coarse leaves attached to a fleshy crown during its first year. In late spring of the second year, a main stem with side branches rapidly grows or "runs" to a height of 4 to 7 feet and bears a spiny head at each terminal. When these heads are in the correct stage of development they are removed from the plant together with some 8 inches of stem. This is a hand operation, since the heads mature at three or four different times, depending on the part of the plant to which they may be attached. The harvested heads are placed in large, aerated sheds to cure, after which the salables are trimmed, graded to size and shipped to various textile mills. These teasel heads must be of uniform cylindrical shape and bear strongly attached spines in order to serve their purpose in finishing fine woolens.

The production of "puff balls" instead of sound heads, and the failure of second year plants to produce heads have resulted in various degrees of losses due to nematode infection. These losses have ranged from a trace, in a number of cases, to complete destruction, in a few isolated fields.

The bulb and stem nematode, *Ditylenchus dipsaci*, was first described by Kühn (*2*) in 1857 as the cause of "Kernfäule" of the inflorescence in fullers teasel, *Dipsacus fullonum* L. His description of the symptoms of nematode infection in teasels was confined to the characteristic misshapen, "soft shelled" heads or puff balls instead of the normal burs. Later, Ritzema Bos (*3*) reported negative results in his attempts to transfer the rye, onion and hyacinth populations of the bulb and stem nematode to teasel seedlings. His work was restricted since he had never observed nematode infection of teasel plants. These early investigations were quoted by later workers and little in addition was accomplished until Thorne (*4*) in 1945 illustrated and amended the diagnosis of the teasel nematode from the Pacific Northwest.

SYMPTOMS OF NEMATODE INFECTION

Bulb and stem nematodes usually enter teasel plants in the young seedling stage during prolonged moist conditions. They feed and reproduce in the young crowns and leaves, causing large populations to be built up under favorable circumstances. When the bud for the central shoot develops from an infected crown during the second year many nematodes attack the tissue surrounding the growing point, reproduce rapidly and are carried upward by plant growth. They are present, therefore, when the growing points terminate in developing teasel heads or burs. The woody, vascular bundles surrounding the pith in the teasel head are so weakened by this infection that the bur gradually widens to a more or less spherical soft-walled mass. As the puff ball matures and becomes dry the nematodes collect in whitish masses in and near the pith as well as becoming attached to the

Fig. 1.—Teasel field showing severe nematode infection.

Fig. 2.—Close-up view of teasel plants, with their crowns cut open. Normal plant on right and infected plant on left. The pressure of cutting caused the weakened crown to break into the four sections.

pedicel of each seed. These nematode masses and those attached to the seed enter a quiescent stage in which they can live for at least 23 years, if kept dry, according to Fielding (*1*). Upon becoming moist the nematodes revive and may remain active for a year or two in moist soil without their host plant.

First year plants which are lightly infected may apparently grow well and give little indication of their weakened crowns. Moderately infected plants may survive during favorable seasons but are too weak to withstand poor growing conditions. Heavily infected plants develop leaves with discolored areas along their midribs, are often unduly curled and gradually die. In such cases the infection is chiefly concentrated in the crown, the tissue of which becomes discolored and progressively necrotic until, in last stages, only a tangled mass of vascular bundles remains within the crown covering. The discolored and distorted tissues contain all stages of these nematodes.

Second year plants which are lightly infected may appear normal with the exception of a few soft malformed heads. Moderately infected plants may be considerably dwarfed, produce puff balls instead of normal heads and often die prematurely.

TRANSFER OF TEASEL NEMATODE TO OTHER PLANTS

Studies of transfer of the present nematode from teasels to other plants were prompted by the finding of a few areas of infestation in a field of teasels which had not produced this crop for more than 10 years. As the teasel seed used for planting had been hot-water treated and was therefore nematode free, it appeared that the infestation had remained in the soil for that period of time, especially since no obvious method of spread could be determined. The following weeds growing on these areas were examined for nematode infection, with the results shown in Table 1.

As noted above, the only weeds having a nematode infection were the large-flowered collomia and the buckhorn plantain. No symptoms, however, were found in either of these plants. The plantain contained only limited numbers of preadult nematodes and very young adult forms, while considerable numbers of nematodes in all stages of

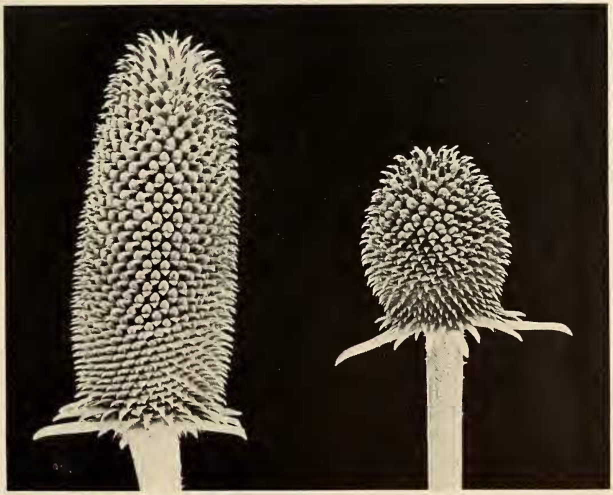

Fig. 3.—Teasel heads, normal on left and infected (puff ball) on right.

Table 1.—Number of Infected Weed Plants Growing in Soil Infested with the Teasel Nematode

Plant	Total plants examined	Plants infected
Amaranth, redroot (*Amaranthus retroflexus* L.)	12	0
Bent grass, redtop (*Agrostis alba* L.)	4	0
Camomile, mayweed (*Anthemis cotula* L.)	20	0
Catsear, spotted (*Hypochoeris radicata* L.)	20	0
Collomia, large-flowered (*Collomia grandiflora* Dougl.)	35	20
Dandelion (*Taraxacum officinale* L.)	16	0
Dock, curly (*Rumex crispus* L.)	5	0
Fern, bracken (*Pteridium aquilinum pubescens* Underw.)	13	0
Fleabane, horseweed (*Erigeron canadensis* L.)	10	0
Gilia, skunkweed (*Gilia squarrosa* H. and A.)	5	0
Goosefoot, lambsquarters (*Chenopodium album* L.)	9	0
Knotweed, prostrate (*Polygonum aviculare* L.)	4	0
Lettuce, prickly (*Lactuca serriola* L.)	9	0
Plantain, buckhorn (*Plantago lanceolata* L.)	40	3
Radish, wild (*Raphanus raphanistrum* L.)	10	0
Ryegrass, Italian (*Lolium multiflorum* Lam.)	18	0
Salsify, meadow (*Tragopogon pratensis* L.)	10	0
Shepherdspurse (*Capsella bursa-pastoris* (L.) Moench)	3	0
Sorrel, sheep (*Rumex acetosella* L.)	20	0
Sowthistle, common (*Sonchus oleraceus* L.)	5	0
Thistle, bull (*Cirsium lanceolatum* (L.) Scop.)	14	0
Total	282	23

Table 2.—Number of Infected Crop Plants Growing in Soil Infested with the Teasel Nematode and in Greenhouse Tests with Inoculum from Oats

Crop plant	Field Grown		Greenhouse Grown
	Spring	Winter	
	15 plants of each variety examined	48 plants of each variety examined	20 plants of each variety examined
Barley (*Hordeum vulgare* L.)	0	0	0
Clover, Hubam (*Melilotus alba* var. *annua* Coe)	0	0	0
Clover, crimson (*Trifolium incarnatum* L.)	0	0	0
Clover, red (*Trifolium pratense* L.)	0	0	1
Corn (*Zea mays* L.)	0	0	0
Oats, spring (*Avena sativa* L.)	0	15	6
Oats, winter (*Avena sativa* L.)	0	16	13
Peas, field (*Pisum sativum arvense* L.)	0	0	0
Rye, Rosen (*Secale cereale* L.)	0	0	8
Teasels (*Dipsacus fullonum* L.)	0	30	12
Vetch (*Vicia sativa* L.)	0	0	0
Wheat, spring (*Triticum aestivum* L.)	0	14	14
Wheat, winter (*Triticum aestivum* L.)	9	18	11

Table 3.—Percentage of Germination of Teasel Seed Treated in Water at Different Temperatures, Durations, and Chemicals Added (Germination Tests Determined at Seed Laboratory, Oregon State College)

Duration	Temp. °F.	Water	Water + Vatsol[1]	Water + Formalin[2]	Vatsol + Formalin[3]
(Untreated check)		91.6	90.7	93.1	93.2
1 hour	75	89.5	90.2	13.5	32.0
	120	78.5	61.2	40.5	0.0
	122	57.5	46.5	0.0	0.0
2 hour	75	89.5	92.5	6.0	14.7
	120	41.2	40.5	0.0	0.0
	122	12.0	9.7	0.0	0.0

[1] Vatsol O.S. used at rate of 8 oz. in 100 gallons of water.
[2] Formaldehyde solution U.S.P. 1 pint in 25 gallons of water.
[3] Vatsol and formaldehyde combined at the above rates.

development were usually found in the collomia.

During the early spring of the following year attention was called to the unusual appearance of another field in which winter oats had been planted following an infected teasel crop. The uneven growth in this field showed as prominent spots of dead and dying oat plants. Upon examination these distorted plants resembled the "segging" or "tulip-root" as described by various workers and contained huge numbers of teasel nematodes. This observation indicated that winter oats might also have been serving as a host of the teasel nematode. To test this theory, oat plants infected from this soil were used to inoculate various crop plants growing in sterilized soil in pots in greenhouse tests listed in Table 2.

The same kinds of crop plants used in these greenhouse tests were also planted in a field which had recently produced heavily infected teasels. The weather was warm and dry that spring so that these plants rapidly grew to maturity and showed little infection upon examination. The following autumn they were re-planted on the same soil and slowly grew through the winter, under wet conditions. Results of the examination of both spring and fall planted crop plants, at their maturity, are presented in Table 2.

The infected crop plants listed above contained bulb and stem nematodes in all stages of development. These data show that several crop plants including oats, red clover, rye and wheat act as carriers of bulb and stem nematodes infecting teasels. It was possible to transfer the disease from winter oats to teasels and it may be that similar transfers could have been made from the other hosts if time and facilities had permitted their study. Evidently plants which grow over winter after autumn seeding are more likely to become infected than fast growing annuals seeded in the spring. This is probably due to the increased opportunity for nematode invasion because of the prolonged seedling stage and wet surroundings of autumn planted seed.

CONTROL

There are two chief sources of nematode infection of teasel plants and both are the result of contamination. These two sources are nematodes on the seed used for planting and nematodes remaining in the soil after

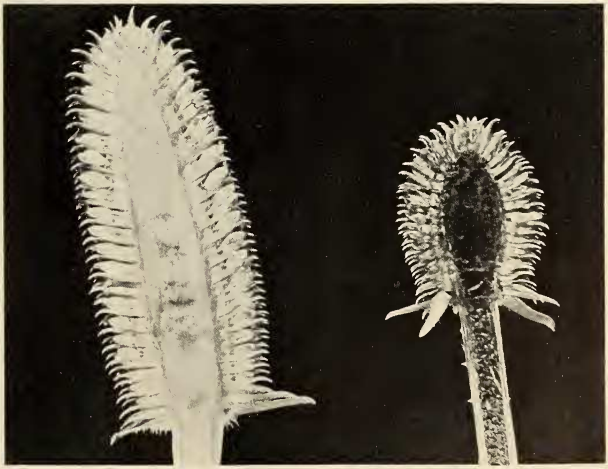

Fig. 4.—Same as Fig. 3 except the heads are cut open. Note the healthy pith in the normal head and discoloration in the infected head.

FIG. 5.—Infected teasel leaf. Note discolored areas along midrib.

an infected teasel or other host crop or weed has grown on the field. Control is a matter of eliminating these nematodes, as follows:

1. Teasel seed should be treated in hot water at 122°F. for one hour, or 120°F. for two hours in order to obtain a complete nematode kill. Experiments used in establishing these treatments included the use of formaldehyde solution and a wetting agent (Vatsol O.S.) in the treating bath, as these materials had previously increased the nematode killing power of this bath as used for narcissus bulbs. The germination of teasel seed exposed to these treatments is given in Table 3. In addition to the germination tests, the treated seed was planted in the field and readings were later taken on the early growth, mid-season growth, final stand, and condition of mature teasel heads and spines.

An examination of the above data together with that of criteria mentioned earlier indicated that:

a. Formaldehyde solution used in the treating water is harmful to the germination of teasel seed and also to the later growth of the plants.

b. Vatsol O.S. used in the treating water exerts little influence on the germination of teasel seed or the later growth of the plants.

c. Teasel seed may be treated at 122°F. for one hour or 120°F. for two hours in water with or without Vatsol. Such treatments reduce the seed germination, however, so that twice as much treated seed must be planted in order to secure normal field stands of teasels. Fortunately this is an unimportant factor, due to the abundance of seed produced by this crop. Teasel plants resulting from treated seed showed increased mid-season growth, more vigorous and upright mature plants with increased number of heads and normal stiffness of spines.

2. Soil can be freed of *D. dipsaci* by rotation with crops which are not host plants, provided it is kept free of weeds, especially in wet seasons.

FIG. 6.—Normal teasel leaf.

Nematode infection of teasel plantings became nearly non-existent as a result of planting hot-water-treated teasel seed on properly managed soil. Fields known to be infested were plowed or disked in the autumn to destroy all growing plants and seeded the following spring to fast growing annuals to be harvested or used as a cover crop. After a 3-year period these fields were relatively free of nematode infestation, providing the residue from the former teasel crop had been properly destroyed.

SUMMARY

The nematode *Ditylenchus dipsaci* has been recorded as doing extensive damage to teasel crops in the Pacific Northwest, when proper control measures were not used.

Infected teasel plants may be dwarfed in appearance, having leaves with discolored areas along their midribs, later dying. The crown is often discolored and may be rotted to various degrees. Top growth from such crowns may be of normal size, but bear misshapen heads or burs, known as puff balls. In severe cases no top growth is produced.

In a series of tests made, plants which became heavily infected with bulb and stem nematodes from teasels, were large flowered collomia, oats (winter and spring types), rye, and wheat (winter and spring types). Buckhorn plantain and red clover plants contained a few nematodes, which were unable to reproduce. Corn, crimson clover, Hubam clover and field peas failed to become infected.

Control consists of eliminating the two main sources of infection, namely, the nematodes remaining in the soil after an infected crop has been harvested and those with the seed. Nematodes are eliminated from the soil by rotation with resistant crops, special attention being given to weed control, and from the seed by treatment with hot water.

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NEW MEMBERS OF THE ACADEMY

There follows a list of persons elected to membership in the Academy, by vote of its Board of Managers, since April 1, 1950, who have since qualified as members in accordance with the bylaws (see also this JOURNAL **40**: 302–306, 1950).

RESIDENT

Elected April 17, 1950

Chan-Mou Tchen, physicist, National Bureau of Standards, in recognition of his contributions to the theory of fluid mechanics, especially the application of statistical methods to motion of small particles and chain molecules, and the treatment of flow problems involving heat addition.

Elected June 18, 1951

Francis C. Breckenridge, physicist, National Bureau of Standards, in recognition of his contributions to aviation lighting and signal colors, and in particular for the evaluation of approach light systems, the development of a chromaticity diagram and the coordination of signal colors, and for his productive work with the I.E.S. and the I.C.I. in these fields.

Newbern Smith, Central Radio Propagation Laboratory, National Bureau of Standards, in recognition of his contributions to studies of radio propagation and the ionosphere, and their application to problems of radio communication.